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REVIEW AND SYNTHESIS

A multi-scalar classification system for the terrestrial vegetation of the world

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Abstract

An approach is proposed for a general multiscale classification of terrestrial vegetation applicable to the whole world; only the outline and principles are presented. Further development of the system should take place through future national and regional surveys. As in other proposals, there are several levels in this system, of which the upper ones are broad and cover large areas, while the lower ones have a local character. To distinguish it from other approaches, this classification is based on clearly defined and hierarchically sorted criteria: Climate, physiognomy, zonality and biogeography for the upper levels, and site conditions and disturbance, reflected by their floristic composition, for the lower ones. The upper level units are created using a top-down (deductive) approach, while the lower level units are created using a bottom-up (inductive) approach, using the Braun-Blanquet classification as a model for the areas where it is available. Both trestles overlap at level 3: Regional Subbiomes, which are the result of the division of Subbiomes (level 2) and can be underpinned by units of phytosociological classes at level 4. Only the zonal and intrazonal classes can be used for this, as the azonal and those conditioned by disturbance use to exceed the scope of a particular zone.

Syntaxonomic references: Mucina et al. (2016) for high rank syntaxa, with the exception of *Querco-Fagetea* and *Fagetalia sylvaticae* which follow Loidi (2020); Rivas-Martínez et al. (2011a) for low rank syantaxa (alliances and associations); Rivas-Martínez (1997) for *Heteromelo arbutifoliae Quercetea agrifoliae*; Krestov et al. (2023) for *Quercetea mongolicae* and Miyawaki et al. (1964) for *Fagetea crenatae*.

Keywords

azonality, bioclimatology, biogeography, Braun-Blanquet approach, disturbance, physiognomy, site conditions, terrestrial vegetation classification, zonality

Introduction

Several comprehensive global classification systems for terrestrial vegetation have been created in the past (Hunter et al. 2021). They are based on different criteria to define the proposed units, e.g. physiognomic, climatic, structural, functional, species composition, disturbance regime, etc. Some of them, published since the 19th century (Schimper 1898), follow physiognomic criteria with a climatic basis. Among them, the zonobiomes proposed by Walter (1985) is one of the most followed, especially in the German literature (Grabherr 1997; Pott 2005; Schultz 2005; Frey and Lösch 2010); the ecozones defined by Pfadenhauer and Klötzli (2014) are similarly conceptualized and provide a very complete general overview of the globe's vegetation. These approaches are based on zonal units with a large spatial extent and focus on their potential natural vegetation types, covering the entire terrestrial parts of the globe with largely synthetic units.

On the other hand, classification systems for plant communities have also been developed at the local level. These include the Braun-Blanquet approach, which is used intensively, especially in Europe (Guarino et al. 2018). This approach focuses on the description of habitats based on species composition and reflects site conditions and successional status. This approach can be extended to the entire terrestrial areas of the world, but it requires a good knowledge of the flora. This prerequisite has hindered its spread, as the floristic richness is unequal in different parts of the world, as is the knowledge of the flora by the field researchers involved. Therefore, it has only been strongly developed in Europe (Mucina et al. 2024) and a few other areas (Algeria, Argentina, Iran, Japan, Morocco, etc.). Other approaches with a wide geographical scope are the National Vegetation Classification of the USA (https://usnvc.org/) and the Vegetation Classification System of China (China-VCS; Song 2011), but they have been developed to cover an area limited to their national territories and do not provide an approach of global value.

The goal of providing a complete classification system by combining broad physiognomy-based units covering large areas at the global scale and detailed units for the local scale was initially recommended by Beard (1978). Subsequently, several approaches pursuing such a comprehensive goal have been proposed. The most important of them have been published recently, namely the IUCN typology (Keith et al. 2020) and the EcoVeg approach (Faber-Langendoen et al. 2014, 2016, 2025). The Vegetation Classification System of China and the US National Vegetation Classification are also under development; both designed to encompass all levels, from the broadest to the most detailed. However, structural elements that are often linked to different zonalities and disturbance conditions are often classified at various levels, including higher ones. It is then possible to find types resulting from disturbances such as fire or grazing, or units due to edaphic conditions, together with types essentially defined by climate. Our aim is to put order into this issue and to organize hierarchically the criteria from highest to lowest level so that they respond to clear and unambiguous criteria in an approach that is conservative according to much of the available literature.

Proposed classification

This paper proposes a global, comprehensive classification system for terrestrial vegetation that encompasses all spatial scales, from the global to the local level, and that could be used in any part of the world, similar to the EcoVeg or IUCN systems. The difference is that we propose to apply hierarchically sorted criteria for the different levels (Figures 1, 2). In a more recent approach to higher-level vegetation classification (Loidi et al. 2022), physiognomic and climatic criteria are predominant, but no units are offered at a detailed spatial level necessary to provide tools for conservation policy at local and regional scales. In the presented classification, it is assumed that the upper level units (block 1) correspond to those presented by Loidi et al. (2022) and that they follow a deductive top-down categorization as described in this paper. The main criteria for these levels are climate and physiognomy. Level 3 comprises also biogeography (Figure 2), a criterion neglected in that approach and considered necessary to express the diversity linked to geography, which determines the species-pool available in each region (Takhtajan 1986; Loidi and Vynokurov 2024). The lower level units (block 2) are the Braun-Blanquet typology for plant communities (Guarino et al. 2018), which follow an inductive bottom-up construction. At the levels of the Braun-Blanquet approach, zonality, but also azonality and disturbance are precisely reflected by syntaxonomy, since units are constituted by their species composition (Westhoff and van der Maarel 1973; Géhu and Rivas-Martínez 1981; Mucina et al. 2016). The same applies to other attributes of vegetation such as structure.

In summary, the levels can be described as follows:

Level 1. This level is constituted by the Domain and Ecozone levels in Loidi et al. (2022). The main criterion used at this level is climate in a general sense at the global level. It was subdivided into level 1a for the Domains, defined only by their general thermal and xeric regime and 1b for the Ecozones that include the seasonality of precipitation and the extreme continentality in their bioclimatic definition (Tables 1, 2).

Level 2. Units at this level include general physiognomic features (evergreen forests, coniferous forests, shrubland, grassland, desert, etc.) that respond to climatic variability. They are the Biomes and Subbiomes in Loidi et al. (2022). This concept includes all the organisms, ecological conditions and processes that take place in them. So far there are 9 Biomes (Level 2a) and 20 Subbiomes (Level 2b), which are the result of the division of the units of the upper level. The global distribution of Subbiomes is shown in the map of Suppl. material 1: figure S1 (extracted from Loidi et al. 2022).

Level 3. This is the new level formed by the Regional Subbiomes. Each Subbiome is represented in the different biogeographical territories of the world (Loidi and Vynokurov 2024) and this makes it possible to recognize the different species pools in which each Subbiome is immersed providing their floristic-phylogenetic content. This opens the door for the Subbiomes level units to define and substantiate the 84 Regional Subbiomes recognized so far. Suppl. material 2: figures S2–S7 include continental maps showing the approximate location of Regional Subbiomes without precisely limiting their areas; more detailed regional surveys will be needed for such accuracy. Each of these Regional Subbiomes will, if available, be characterized by one or several of the Braun-Blanquet vegetation classes of level 4. These classes can be of zonal or intrazonal character as far as they are exclusive of the involved region.

Table 1. Scheme of the classification of the upper levels of the system (block1): Level 1 (Domains and Ecozones), with the bioclimatic types in which they are framed, and Level 2 (Biomes and Subbiomes), both corresponding to those described by Loidi et al. (2022). The 84 Regional Subbiomes are listed in the Level 3 column. The correspondence of the Regional Subbiomes with the 6 Thermotypes and the 7 Ombrotypes is indicated with an x. Bioclimatic variables and indexes used for the delimitation of Thermotypes and Ombrotypes are explained in Table 2.

Level 1		Level 2		Level 3	Thermotypes (Tp)						Ombrotypes (Io)						
Domain and Macrobioclimate (Tp and Io)	**Ecozone** and Bioclimate	Biomes	Subbiomes	Regional Subbiomes	Infra	Thermo	Meso	Supra	Oro	Cryoro	Hyperarid (< 0.4)	Arid (0.4–1)	Subarid (1–2)	Dry (2–3.6)	Subhumid (3.6–6)	Humid (6–12)	Hyperhumid (> 12)
Cryocratic; Cold (Tp < 1000)	**Polar and boreal ecozone**; Tundral-boreal	1. Tundra	1a. Polar tundra	**1a.1. Circumarctic polar tundra**						x				x	x	x	x
				1a.2. Antarctic polar tundra						x						x	x
			1b. Tundras of the temparate mountains in cryoro belt	**1b.1. Eurasian mountains cryoro tundras**						x						x	x
				1b.2. North American mountains cryoro tundras						x						x	x
				1b.3. Austral mountains cryoro tundras						x						x	x
			1c. Tundras of the tropical mountains in cryoro belt	**1c. 1. Paleotropical mountains cryoro tundras**						x						x	x
				1c. 2. Neotropical mountains cryoro tundras						x						x	x
		2. Boreal forests	2a. Lowland boreal Taiga	**2a. 1. Circumboreal Taiga**					x					x	x	x	x
				2a.2. Magellanic Taiga					x							x	x
			2b. Forests and shrublands of the temperate oro belt	**2b.1. Eurasian mountains oro Taiga**					x							x	x
				2b.2. North American mountains oro Taiga					x						x	x	
Mesocratic; Mesic (1000 < Tp < 2000)	**Temperate ombroestival ecozone**; Pluviestival (rainy summer), dws > 1, BIO7 < 300	3. Temperate deciduous forests	3a. Temperate deciduous forests	**3a.1. Western Eurasian temperate deciduous forests**			x	x							x	x	x
				3a.2. Eastern Eurasian temperate deciduous forests			x	x						x	x	x	x
				3a.3. Eastern North American temperate deciduous forests			x	x							x	x	
				3a.4. Valdivian temperate deciduous forests			x	x								x	x
		4. Temperate pluvial evergreen forest, shrublands and grasslands	4a. Lowland evergreen lauroid and conifer forests and grasslands	**4a.1. Chinese-Japanese evergreen forests**	x	x	x									x	x
				4a.2. North American atlantic evergreen forests	x	x	x								x	x	
				4a.3. Southeastern African evergreen forests		x	x							x	x		
				4a.4. South Brazilian (Paraná, Sta. Catarina) and Misiones *Arucaria angustifolia* forests		x	x									x	
				4a.5. Pampean grasslands and evergreen woodlands	x	x	x								x		
				4a.6. Tasmanian southeastern Australian evergreen forests		x	x	x							x	x	x
				4a.7. Valdivian-Magellanic evergreen forests			x	x							x	x	x
				4a.8. New Zealand evergreen forests		x	x	x							x	x	x
			4b. Conifer coastal forests	**4b.1. Pacific coast North American conifer forests**			x	x								x	x
			4c. Tropical montane cloud lauroid and conifer evergreen forest	**4c.1. Chinese-Japanese montane evergreen forests**			x	x								x	x
				4c.2. Macaronesian montane cloud evergreen forests		x	x								x	x	x
				4c.3. Ethiopian-Southarabian and tropical African montane evergreen forests		x	x	x							x	x	x
				4c.4. Southeastern African montane evergreen forests			x	x							x	x	x
				4c.5. St. Helena and Ascension montane evergreenn forests			x	x							x	x	
				4c.6. Indo-Malesian montane evergreen forests		x	x	x							x	x	x
				4c.7. Pacific islands montane evergreen forests		x	x	x								x	x
				4c.8. Madrean montane evergreen forests			x	x						x	x		
				4c.9. Antillean-Mesoamerican montane evergreen forests			x	x							x	x	x
				4c.10. Guyanan montane evergreen forests		x	x	x								x	x
				4c.11. Andean montane evergreen forests			x	x								x	x
	Temperate aridiestival ecozone; Aridiestival (dry summer),dws < 1	5. Temperate aridiestival evergreen forests and shrublands	5a. Oceanic sclero-pyllous-microphyllous evergreen forests and shrublands (Mediterranean)	**5a.1. Mediterranean basin sclerophyllous-microphyllous evergreen forests and shrublands**		x	x	x				x	x	x	x		
				5a.2. Californian sclerophyllous-microphyllous evergreen forests and shrublands			x					x	x	x	x		
				5a.3. Capensis sclerophyllous-microphyllous evergreen shrublands		x	x						x	x	x		
				5a.4. Central Chilean sclerophyllous-microphyllous evergreen forests and shrublands		x	x	x					x	x	x		
				5a.5. Southwestern Australian sclerophyllous-microphyllous evergreen forests and shrublands		x	x						x	x	x	x	
			5b. Continental scrub and woodlands	**5b.1. Iberian-North African Juniper-Pinus woodland**				x					x	x	x		
				5b.2. Irano-Turanian conifer-broadleaved woodland				x					x	x	x		
				5b.3. Western North American pinyon-juniper woodlands				x	x				x	x			
				5b.4. Southeastern Australian Eucalypt-Callitris woodland			x	x						x	x		
			5c. Patagonian shrubland	**5c.1. Patagonian sclerophylle evergreen shrubland**			x	x	x			x	x	x			

Level 1		Level 2		Level 3	Thermotypes (Tp)						Ombrotypes (Io)						
Domain and Macrobioclimate (Tp and Io)	**Ecozone** and Bioclimate	**Biomes**	**Subbiomes**	**Regional Subbiomes**	**Infra**	**Thermo**	**Meso**	**Supra**	**Oro**	**Cryoro**	**Hyperarid (< 0.4)**	**Arid (0.4–1)**	**Subarid (1–2)**	**Dry (2–3.6)**	**Subhumid (3.6–6)**	**Humid (6–12)**	**Hyperhumid (> 12)**
Mesocratic; Mesic (1000 < Tp < 2000)	**Temperate hiper-continental steppic ecozone;** Steppic, BIO7 > 300	6. Steppes	6a. Forest-steppe	**6a.1. Eurasian forest-steppe**				x						x	x		
				6a.2. North American forest-steppe		x	x	x							x		
			6b. Grass-steppe	**6b.1. Eurasian grass-steppe**				x					x	x			
				6b.2. North American grass-steppe		x	x	x						x			
Xerocratic; Arid (Io < 1)	**Ecozone of the deserts and semi-deserts of arid regions;** Desertic	7. Deserts and semi-deserts	7a. Cold deserts and semi-deserts	**7a.1. Irano-Turanian cold deserts**				x	x		x	x	x				
				7a.2. Western North American cold deserts				x	x			x	x				
			7b. Temperate deserts and semi-deserts	**7b.1. Saharo-Sindian, Irano-Turanian and Macaronesian temperate deserts**	x	x	x	x			x	x					
				7b.2. West North American temperate deserts (Mojave)			x	x			x	x	x				
				7b.3. Madrean temperate deserts (Chihuahua)			x	x				x	x				
				7b.4. Karoo-Namibian temperate deserts		x	x				x	x					
				7b.5. Central Australian temperate deserts		x	x					x	x				
			7c. Warm deserts and semi-deserts	**7c.1. Saharo-Sindian warm deserts**	x	x					x	x					
				7c.2. Ethiopian Southarabian warm deserts	x	x					x	x					
				7c.3. Karoo-Namibian warm deserts		x					x	x					
				7c.4. Madrean warm deserts (Sonora)		x	x				x	x	x				
				7c.5. Pacific coast south American warm deserts		x	x				x	x					
				7c.6. Central Australian warm deserts	x	x						x	x				
Thermocratic; Warm (Tp > 2000)	**Tropical pluviseasonal ecozone;** BIO15 > 60, rainy and dry season	8. Tropical pluviseasonal forests and shrublands	8a. Tropical xeric shrublands and woodlands	**8a.1. Tropical African xeric shrublands and woodlands**	x	x						x	x	x			
				8a.2. Indian xeric shrublands and woodlands	x	x							x	x			
				8a.3. Mesoamerican xeric shrublands and woodlands	x	x							x	x			
				8a.4. Southern American xeric shrublands and woodlands	x	x							x	x			
				8a.5. Central Australian tropical xeric shrublands and woodlands		x							x				
			8b. Tropical pluviseasonal forests and woodlands	**8b. 1. Tropical African pluviseasonal shrublands and woodlands**	x	x	x							x	x		
				8b. 2. Malagasy pluviseasonal shrublands and woodlands	x	x	x						x	x	x		
				8b. 3. Indian pluviseasonal shrublands and woodlands	x	x								x	x		
				8b. 4. Southeastern Asian and Malesian pluviseasonal shrublands and woodlands	x	x								x	x	x	
				8b. 5. Neocaledonian pluviseasonal shrublands and woodlands		x									x	x	
				8b.6. Polynesian pluviseasonal shrublands and woodlands	x	x									x	x	
				8b.7. Antillean Mesoamerican pluviseasonal shrublands and woodlands	x	x									x	x	
				8b.8. South American pluviseasonal shrublands and woodlands	x	x								x	x		
				8b.9. North Australian pluviseasonal shrublands and woodlands	x	x							x	x			
	Tropical pluvial ecozone; BIO15 < 60, rainy all the year round	9. Tropical rain forests	9a. Tropical rain forests	**9a. 1. Guinean-Congolese tropical rain forests**	x	x									x	x	x
				9a. 2. Malagasy tropical rain forests		x										x	x
				9a. 3. Indian tropical rain forests	x	x										x	x
				9a. 4. Southeastern Asian and Malesian tropical rain forests	x	x										x	x
				9a. 5. Pacific Islands tropical rain forests	x	x										x	x
				9a. 6. Antillean-Mesoamerican tropical rain forests	x	x										x	x
				9a. 7. Amazonian and Orinoco tropical rain forests	x											x	x
				9a. 8. Mata Atlântica tropical rain forests		x	x									x	

Levels 4, 5, 6 and 7 correspond to the four hierarchical units of the Braun-Blanquet system: Class, Order, Alliance, and Association. All these units are characterized by their species composition, which reflects the environmental variables that influence each of them: substrate (soil texture, nutrient and moisture availability), temperature, biogeography (regional species pool) and successional position (dynamics and disturbance conditions). The syntaxonomic hierarchy is structured inductively, so that floristically (and ecologically) related units of lower rank combine to form units of higher rank. The criteria to define these four levels have been repeatedly established (Westhoff and van der Maarel 1973; Géhu and Rivas-Martínez 1981). The highest level of this system is the Class, which represents level 4 in this system, and can be used advantageously to underpin level 3 units. Some important attributes of vegetation, such as structure

Table 2. Bioclimatic variables and indexes used for the bioclimatic classification. Additional information on Tp is provided in Suppl. material 5.

Index	Description	Source
BIO7	Temperature Annual Range: BIO5 (Max Temperature of Warmest Month) -BIO6 (Min Temperature of Coldest Month)	CHELSA (Karger et al. 2017, 2018)
BIO10	Mean Temperature of Warmest Quarter	CHELSA (Karger et al. 2017, 2018)
BIO15	Precipitation Seasonality (Coefficient of Variation)	CHELSA (Karger et al. 2017, 2018)
BIO18	Precipitation of Warmest Quarter	CHELSA (Karger et al. 2017, 2018)
nfd	number of frost days	CHELSA (Karger et al. 2017, 2018)
dws	drought of the warm season (BIO18/BIO10)	CHELSA (Karger et al. 2017, 2018)
Io	Ombrothermic index, quotient between the positive precipitation and positive temperature: Pp/Tp.	Rivas-Martínez et al. (2011b)
Pp	Positive precipitation, sum of the mean precipitations of the months in which t > 0; $\sum^{12}_{i=1}$ when $t_i > 0$	Rivas-Martínez et al. (2011b)
Tp	Positive temperature, sum of the mean temperatures of the months in which t > 0; $\sum^{12}_{i=1} \times 10$, when $t_i > 0$ (See Suppl. material 6)	Rivas-Martínez et al. (2011b)

(forest, shrubland, grassland, etc.), related to disturbance, such as fire, mowing, or herbivorous predation, etc., or site conditions such as flooding, rockiness, abundance of organic nutrients, etc., are automatically represented at these lower levels by the species composition and abundance data that the Braun-Blanquet system entails.

In comparison with the abovementioned approaches of IUCN and EcoVeg, this classification in characterized by the following traits:

1. A hierarchization of the defining criteria for the units in the different levels. The upper levels are not defined after azonality and disturbance and consequently they do not reflect structure such as being forest, shrubland or grassland. Upper levels are defined by climate, physiognomy (more or less loosely on the zonal unit) and geography, globalizing the vegetation content within each unit. Azonality and disturbance are expressed in the lower levels, after the Braun-Blanquet or similar floristic-based approach.
2. Climate is framed into the bioclimatic classification provided by Loidi et al. (2022) matching the higher level units of this classification in order to formalize definitions and limits.
3. All the levels are defined by vegetation conceived at different integration levels. It is considered that ecological conditions are inherent to the vegetational envelope as it provides structure and primary production to the ecosystem.
4. This classification is only about terrestrial vegetation, not including aquatic marine or freshwater ecosystems.

Criteria for classification

The system proposed in this work tries to have a universal value and establishes a hierarchy of criteria used to define the different levels (Figure 2). Clear criteria are followed in all levels, climatic-physiognomic in the upper ones (block 1) and floristic-ecological in the lower ones (block 2). The connecting unit for the two level blocks is the newly proposed level 3 of the Regional Subbiomes, which represent geographical versions of the Subbiomes. They are deductively defined as subdivisions of Subbiomes of level 2, taking into account the biogeographical unit(s) in which they are located. They are based on the biome concept, i.e. a comprehensive unit encompassing all biota and all functional aspects of terrestrial ecosystems (Mucina 2019, 2023; Hunter et al. 2021). As mentioned above, the particular flora of each region provides biotic elements for distinguishing between the different Regional Subbiomes of a Subbiome. This floristic differentiation is expressed by using the biogeographical realms and regions proposed by Loidi and Vynokurov (2024). In this first approach, 84 Regional Subbiomes are recognized and listed (Figure 1, Table 1). Their distribution on the individual continents is shown on the maps in Suppl. material 2: figures S2–S7. In addition, the highest level of the Braun-Blanquet block, the level 4 Class, can also be used to underpin their concept, similar to what Willner and Faber-Langendoen (2020) and Faber-Langendoen et al. (2025) proposed for the formations. Part of the classes are fundamentally zonal in their character and fit into the Regional Subbiomes; they are labeled Z in Figure 1. For example, *Querco-Fagetea* fits into the 3a.1. Western Eurasian temperate deciduous forests, *Quercetea mongolicae* and *Fagetea crenatae* share the 3a.2. Eastern Eurasian temperate deciduous forests, *Quercetea ilicis* dominates the 5a.1. Mediterranean basin sclerophyllous-microphyllous evergreen forests and shrublands, as well as *Heteromelo arbutifoliae-Quercetea agrifoliae* is the main unit in the 5a.2. Californian sclerophyllous-microphyllous evergreen forests and shrublands. Intrazonal units could also be used to substantiate these Regional Subbiomes, but they can be found at the level of order, alliance, or association. Of course, there are many of these Regional Subbiomes which at the moment lack such defining classes of vegetation but this is because they have not been described so far. Hopefully, as the national and subnational vegetation surveys progress, they will provide the Regional Subbiomes with such units or equivalent ones.

The dominant criteria at the higher levels are applied to those below in a cascade manner (Figure 2), so that, for example, the climatic criterion is applied to all levels, from 1 to 7, the physiognomy criterion from 2 to 7, the biogeography criterion from 3 to 7 and the environmental conditions and successional state criterion in the four lower levels corresponding to block 2 of Braun-Blanquet units. In this last block, the climatic and physiognomic criteria are fully applied to the zonal units but with less intensity in the azonal units and to those linked to disturbance, since the site conditions and the disturbance regime are respectively their main drivers. Summarizing, the criteria for the classification are:

Zonality. It is the main criterion for the two upper levels and the only one in the first one. Zonal ecosystems are determined by climate as this is the main driver for the units at the global scale (Table 2). In the lower levels (4 to 7) zonality is combined with azonal units (including both extrazonal and intrazonal). Explanations of these concepts are provided by Walter (1954), Walter and Box (1976), Mucina (2019, 2023), Loidi et al. (2022), and Mucina et al. (2024). Suppl. material 3: figures S8, S9 show the topographic model in which zonality and azonality are located, and the ecosystems in which different zonal and azonal types are recognized, respectively (Suppl. material 3).

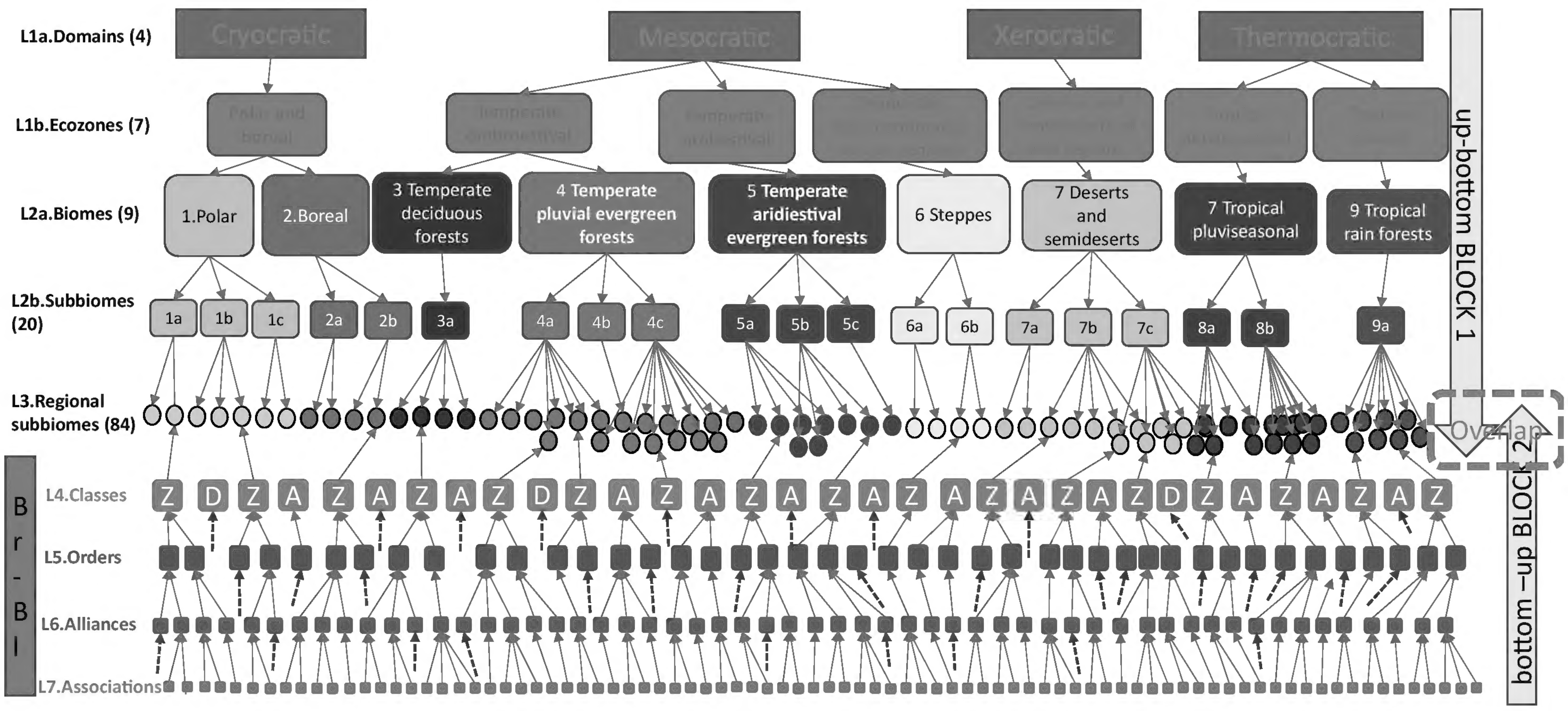

Figure 1. Schematic representation of the multi-scaled classificatory system of vegetation. There are seven levels (and nine sublevels). The number of categories so far recognized in each of the three upper levels is indicated in brackets. Levels 4, 5, 6, and 7 are coincident with Braun-Blanquet levels. The units of Level 3, Regional Subbiomes, are the result of both the division of the subbiomes following biogeography and the content of a zonal class of the level below (Level 4). Levels 1 to 3 are defined top-down while levels 4 to 7 are defined bottom-up. In level 3, that of the Regional Subbiomes, both procedures overlap as zonal classes (Z) can be used to substantiate them. Most of the Azonal (A) and disturbance (D) classes are not used for that purpose.

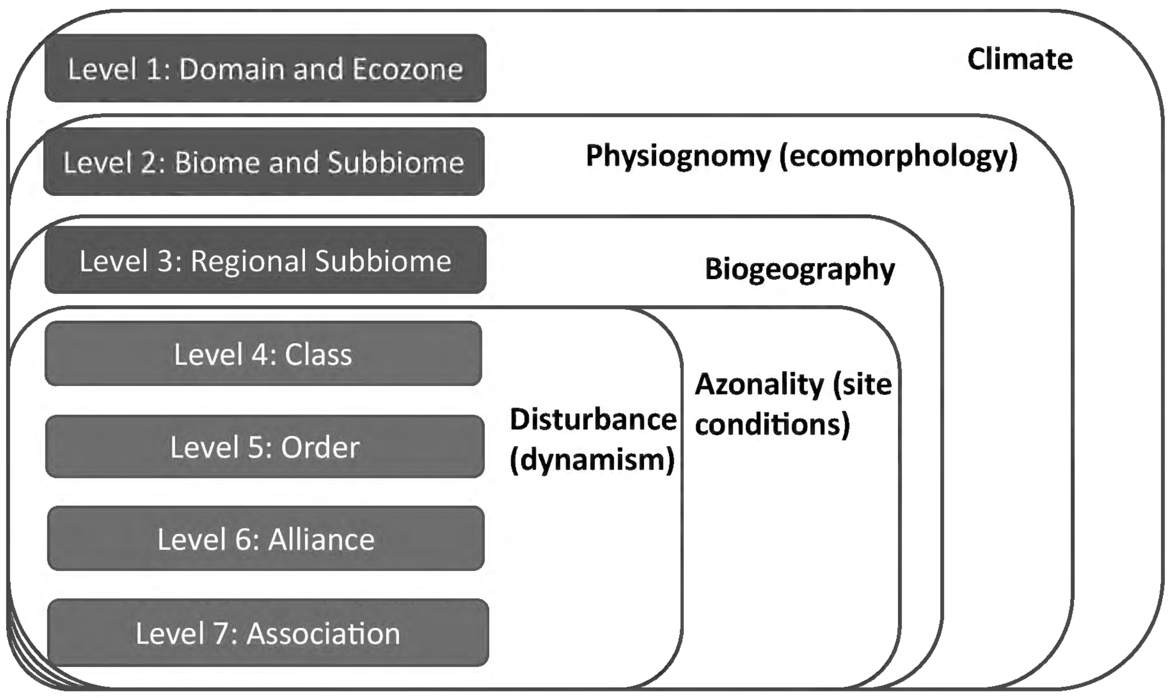

Figure 2. Scheme representing the criteria used to define the different levels. Level 1 is solely defined by climate at a large spatial scale (temperatures and drought). Level 2 (Biomes and Subbiomes) includes also physiognomy and Level 3 (Regional Subbiomes) incorporates biogeography at the region scale. Levels 4 to 7 (Braun-Blanquet levels) are defined by the previous ones but also by their zonal, azonal, or disturbed character. Upper levels (block 1) are in green and lower ones (block 2) in blue.

Physiognomy. It is used at all levels except in the first one. All plant assemblages have a characteristic dominance by some species, which confer their eco-morphologic traits to the community.

Biogeography. According to Loidi (2021a), it is used in increasing detail in levels 3 to 7. In level 3, it is combined with zonality, and the biogeographic units used are the realm and the region, while in the lower levels, provinces or sectors can be applied.

Site conditions (ecology). In levels 4 to 7, site conditions, i.e. topography, substrate quality, and water availability, combined with the other two criteria, zonality (or azonality) and biogeography, are expressed by the floristic composition of the plant communities.

Disturbance. This includes natural as well as human-induced disturbance, being applied in levels 4 to 7. A complete description of the involved phenomena is given in Loidi (2021b). There are classes determined by severe anthropic influence such as *Polygono-Poetea annuae* or *Artemisietea vulgaris* and all the units subordinate to them, as well as others of semi-natural character such as *Calluno-Ulicetea* or *Molinio-Arrhenatheretea elatioris* (order *Arrhenatheretalia elatioris*). A summary of the disturbance phenomena influencing terrestrial ecosystems, both natural and human-induced, is shown in Suppl. material 4. This condition is also expressed by the floristic composition of the communities.

Some examples to apply this classification. Three examples are given in Table 3 to illustrate how this classification

Table 3. The seven levels of the classification with three examples extracted from European cases. Each of the examples has one unit for zonal, azonal, and disturbed vegetation in the lower levels.

A. Top-down	Levels	Defining criteria	Name	Example 1	Example 2	Example 3
Zonal levels	**Level 1. Domain and ecozone**	Broad climatic definition	1a. Domain	Cryocratic	Mesocratic	Mesocratic
			1b. Ecozone	Cryocratic	Temperate aridiestival	Temperate ombroestival
	Level 2. Biome and subbiome	Climatic and physiognomic definition	2a. Biome	Biome of the boreal forest	Biome of the temperate aridiestival evergreen forests and shrublands	Biome of the temperate deciduous forests
			2b. Subbiome	Subbiome of the forests and shrublands of the temperate oro belt	Subbiome of the Oceanic scleropyllous-microphyllous evergreen forests and shrublands (Mediterranean)	Subbiome of the temperate deciduous forests
	Level 3. Regional subbiome	Climatic and physiognomic definition, regional version based on **Biogeography** at the level of region or group of regions	3. Regional formation	Regional formation of the oro areas (subalpine) of the old world temperate mountains	Regional formation of the sclerophyllos-microphyllous forests and woodlands of the Mediterranean and Irano-Turanian regions	Regional formation of the temperate deciduous forests of Western Eurasia
B. Bottom-up	**Levels**	**Defining criteria**	**Name**	**Example 1**	**Example 2**	**Example 3**
Zonal, azonal and disturbed levels	**Level 4. Class**	Floristic-ecologic definition. Biogeography at the level of region, Azonal and disturbed types are included	4a. Zonal	Class *Vaccinio-Piceetea*	Class *Quercetea ilicis*	Class *Querco-Fagetea sylvaticae*
			4b. Azonal	Class *Asplenietea trichomanis* (rocky cliffs)	Class *Molinio-Arrhenatheretea* (managed mesic and wet grasslands)	Class *Phragmito-Magnocaricetea*
			4c. Disturbed	Class *Mulgedio-Aconitetea* (nutrient-rich)	Class *Ononido-Rosmarinetea* (pyrophytic scrub)	Class *Molinio-Arrhenatheretea* (managed mesic and wet grasslands)
	Level 5. Order	Floristic-ecologic definition Biogeography to the level of region. Azonal and disturbed types are included	5a. Zonal	Order *Athyrio filicis-feminae-Piceetalia*	Order *Quercetalia ilicis*	Order *Fagetalia sylvaticae*
			5b. Azonal	Order *Potentilletalia caulescentis*	Order *Holoschoenetalia*	Order *Nasturtio-Glycerietalia*
			5c. Disturbed	Order *Senecioni rupestris-Rumicetalia alpini*	Order *Rosmarinetalia officinalis*	Order *Arrhenatheretalia elatioris*
	Level 6. Alliance	Floristic-ecologic definition. Azonal and disturbed types are included. Regional scale (Province)	6a. Zonal	Alliance *Seslerio caeruleae-Pinion uncinatae*	Alliance *Quercion ilicis*	Alliance *Pulmonario longifoliae-Quercion roboris*
			6b. Azonal	Alliance *Saxifragion mediae*	Alliance *Molinio-Holoschoenion*	Alliance *Glycerio-Sparganion*
			6c. Disturbed	Alliance *Rumicion alpini*	Alliance *Sideritido incanae-Salvion lavandulifoliae*	Alliance *Cynosurion cristati*
	Level 7. Association	Floristic-ecologic definition. Azonal and disturbed types are included. Local scale (sector)	7a. Zonal	Association *Rhododendro ferruginei-Pinetum uncinatae*	Association *Asparago acutifolii-Quercetum rotundifoliae*	Association *Polysticho setiferi-Fraxinetum excelsioris*
			7b. Azonal	Association *Asperulo hirtae-Potentilletum alchimilloidis*	Association *Cirsio monspessulani-Holoschoenetum vulgaris*	Association *Glycerio declinatae-Apietum nodiflori*
			7c. Disturbed	Association *Chenopodio boni-henrici-Rumicetum pseudalpini*	Associacion *Lino differentis-Salvietum lavandulifoliae*	Association *Lino biennis-Cynosuretum cristati*

system could be applied. In example 1, we start from the bottom-up in a subalpine area in the Pyrenees where the zonal vegetation is a pine forest of the association *Rhododendro ferruginei-Pinetum uncinatae*. Nearby, there are azonal communities such as limestone rock crevices communities (*Asperulo hirtae-Potentilletum alchimilloidis*) or disturbed ruderal vegetation areas (*Chenopodio boni-henrici-Rumicetum pseudalpini*). Of course, each of these associations belongs to its respective alliances (level 6), orders (level 5) and classes (level 4). In example 2 the location is in central Spain, where the zonal vegetation is represented by the *Asparago acutifolii-Quercetum rotundifoliae*. One of the azonal communities is the wetlands rush community of the *Cirsio monspessulani-Holoschoenetum vulgaris* and a disturbed fire-related community is the *Lino differentis-Salvietum lavandulifoliae.* Example 3 describes the lowland area of the coastal northern Iberian Peninsula where the mixed forest of the *Polysticho setiferi-Fraxinetum excelsioris* represents the zonal potential vegetation. The association *Glycerio declinatae-Apietum nodiflori* represents the azonal wetlands vegetation and the *Lino biennis-Cynosuretum cristati* the semi-natural hay meadows managed by grazing and mowing.

These examples summarize three different climatic and biogeographic situations in three locations. Each of them contains several azonal and disturbed communities which constitute the set of associations linked to the corresponding zonal type, i.e., the Potential Natural Vegetation of the area.

In most territories of the world, there is not an available low-level detailed vegetation classification system, as is the case in most of Europe and other areas thanks to the Braun-Blanquet typology. In such a case, no lower level units are available unless they are provided by specific surveys to be used instead. Not necessarily the units provided in these surveys have to follow phytosociological rules and nomenclature, but it would be convenient they are based in floristic composition or at least species dominance.

Application outcomes

This is a proposal for a comprehensive classification of terrestrial vegetation that could have global application, with few upper level units which diversify downwards into numerous lowest level ones trying to express the existing diversity of the terrestrial ecosystems of the Globe. It provides with explanatory units at all levels described. Such classification can be used:

1. To help organize the increasingly huge amount of ecological and biodiversity data being produced in the world so that a certain scientific global framing of them can be possible.
2. To frame and contextualize surveyed areas so that local field surveys can be compared if performed within the same unit. The level and unit of this classification in which two local surveys are done, for instance, will indicate the degree of comparability between the environmental and biogeographic conditions of the two mentioned surveys performed in separate locations, reporting the comparability of their results. The lower the level, the greater the comparability.
3. For teaching purposes, it provides objective scientific descriptions of the world's territories at different scales.

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Supplementary material

Supplementary material 1
Subbiomes of the world (extracted from Loidi et al. 2022) (.pdf)
Link: https://doi.org/10.3897/VCS.139673.suppl1

Supplementary material 2
Regional Subbiomes of the six continents (figures S2–S7) (.pdf)
Link: https://doi.org/10.3897/VCS.139673.suppl2

Supplementary material 3
Zonality and azonality in terrestrial ecosystems: figure S8. Scheme of a universal value topographic profile model; figure S9. Scheme summarizing the most representative azonal terrestrial ecosystems. (.pdf)
Link: https://doi.org/10.3897/VCS.139673.suppl3

Supplementary material 4
Natural and anthropogenic disturbance phenomena influencing terrestrial vegetation (.pdf)
Link: https://doi.org/10.3897/VCS.139673.suppl4

Supplementary material 5
Table of Tp values to separate Thermotypes across latitude (.pdf)
Link: https://doi.org/10.3897/VCS.139673.suppl5